A Requirement Model of an Adaptive Emergency Evacuation Center Management

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ABSTRACT

Among all natural disasters, flood is not only becoming increasingly dangerous, but is also recording the highest percentage of occurrences. Previous studies on flood disaster have provided solutions to deal with the problem. However, these research do not anticipate the scenario whereby evacuation centers are drowned by heavy flood. Besides, there were also no provision for requirement models which can be used as reference guides. This study proposes a requirement model for a decision aid model for evacuation center management which is capable of providing smart solutions for the relocation of victims to other evacuation centers should the flood level become increasingly dangerous. The methodology used in this study consists of five phases: requirement gathering, conceptual design, development, verification, and preparing thesis & articles for publication. This study has produced a requirement model of the proposed system that consists of a use case diagram, use case specifications, class diagrams, and sequence diagrams, which have been reviewed by experts using inspection method. The proposed requirement model can be used as a reference model for developers in producing similar evacuation center management system.

Keywords: requirement model, smart evacuation center management, flood, relocation.

I INTRODUCTION

Natural disasters have become worldwide issues. 94 countries have been affected by 317 natural disasters in 2014, causing 8,186 deaths worldwide (the International Federation of Red Cross and Red Crescent Societies (IFRC), 2015). Between 1995 and 2015, 6,768 natural disasters occurred (Davies, 2016; Reduction, 2015). These disasters include flood, storm, earthquake, extreme temperature, landslide, drought, wildfire, and volcanic activity.

In the recent 2015 flood tragedy, several evacuation centers (EC) in Kuala Krai were submerged, despite the information that the rescuing teams and EC staff acquired from the e-banjir portal. This portal provides information related to current water level, number of victims at each EC, and quantity of flood supply and other relevant, significant information. However, the decision to reallocate the victims to other safer ECs by the rescuing teams was delayed. Consequently, the victims were only moved to other centers when flood water reached the third floor of one school building that served as an EC (Bernama, 2015). This therefore, has triggered the needs of having a decision support aid that is able to provide solutions to assist EC staff to make quick and accurate decision to reallocate the trapped victims to the safest EC. Rusdi Ishak, an officer of the Kedah Department of Social Welfare, has also expressed the same view (Ishak, 2014).

The numerous research on flood in Malaysia are directed on planning for flood disaster (Ghazali, 2006), designing flood management system (Norliza Katuk, Ku Ruhana Ku-Mahamud, Norita Norwawi, 2009), applying knowledge management concept in managing flood information (Maidin, Othman, & Ahmad, 2014; Yahya, 2014), and flood simulation using Geographical Information Management (Kia et al., 2012). Foreign researchers, on the other hand, concentrate on reallocating victims from their residences to ECs (response phase) and are more focused on flood prevention (preparedness phase). Multi-period optimization model (Gama, Scaparra, & Santos, 2013), maximal covering location problem (MCLP) with Lagrange optimization model (Santos et al., 2013), and Shelter Location-Allocation Model (Kongsomsaksakul, Yang, & Chen, 2005) are some studies on reallocating the resources from people's residences to evacuation centers. They focus on formulation and algorithm. Neither prototype nor requirement model were produced. Early Warning Flood Detection Systems (Basha & Rus, 2007), decision support system (DSS) (Mirfenderesk, 2009), and agent-based discrete event simulation (ABDES) evacuation framework are some studies on prevention (Hyeong Suk Na, 2014). Currently, there is no research yet done to provide solution on reallocating victims when the ECs are almost submerged. A requirement model needs to be established as a foundation to build such system. On the studies stated above, no requirement model was produced. A requirement model represents users' needs which is created through process model (Kumar, 2012; Pressman, 2010).

The specific objectives of this proposed Requirement Model of an Adaptive Emergency Evacuation Center Management (AEECM), which can be accessed from web or mobile devices are: (i) to identify the requirements of AEECM, (ii) to develop a requirement model for AEECM, (iii) to verify and validate the propose requirement model through expert review and prototyping.

This study focuses on deriving the requirements model as is used in Kuala Krai district in Kelantan, Malaysia as a case study for AEECM, where the information on the ECs and rivers are collected. This study is on software development. A case such as an electrical outage and unavailability of internet connection are not taken into account. This model adopts a suitable optimization algorithm. However, no comparison with other algorithms is conducted.

The succeeding sections are organized as follows: Section II describes the main concepts behind this study; Section III presents the methodology used, followed by Section IV, which is the proposed system. The subsequent sections V and VI describe the verification results. Finally, the conclusion is presented.

II BACKGROUND

A. Evacuation

Many studies have been conducted to overcome, and minimize the hazards and risks of disasters. All those studies carry the same characteristics; they reflect on the necessary conditions for evacuation to be effected, persons at risks and require evacuation, safe places, and the evacuation routes to destination.

Gama et al. (2013) present a multi-period optimization model which aims at identifying the optimal location of shelters in the event of a flood disaster. A fixed number of the location of the ECs is determined in each time period and once opened it must remain opened. It assigns the victims from their residences to the ECs based on full coverage objective and a distance objective. It also determines the number of rescuing units allocated to each opened shelter.

The work by Kongsomsaksakul et al. (2005) proposes a model which can be used to determine shelter locations based on their capacity constraints in the event of flood. The model is defined as bi-level programming problem which is different in comparison to traditional location allocation model in location theory. With aims to minimize the total network evacuation time, the number and locations of ECs are determined by the planning authority. However, the researchers do not clearly state how those ECs are determined. The ECs and the route are chosen simultaneously.

Basha & Rus (2007) describe the problem of early warning system and propose sensor network with specific requirement as a solution. For instance, this sensor network monitors events covering a large area of geographic regions, roughly about 10,000 km^2, measures a wide range of varieties of variables that contribute to the occurrence of an event, and detects and predicts river flood by measuring river level, rainfall, and air temperature to detect river flooding. By monitoring this information, flooding events can be predicted. If these information imply flooding, the system will alert the authority and the community around the affected area to enable them to prepare themselves for evacuation to a safer place.

Multi-period optimization model is designed to find the optimal location shelter in the event of a disaster. This model helps by allocating victims to EC. In addition, it also determines which rescue unit to be dispatched to that specific EC. Similarly, Kongsomsaksakul et al. (2005) designed a system to fulfill the same objective as the Multi-period optimization model. In contrast, the early warning flood detection system is designed to detect flood and alert the people around the flood zone.

These combination of works, either by Gama et al. (2013) and Basha & Rus (2007) or the work by Kongsomsaksakul et al. (2005) and Basha & Rus (2007), may help the authority to evacuate the people at risk to safer places. However, as mentioned earlier, an EC which is identified as a safe place, may in fact not as safe as expected. It was reported that several ECs in Kelantan were engulfed by flood water in January 2015. It was also reported that the rescuing team was late in making the decision to reallocate the victims to other safer ECs. Therefore, this prompted the needs of having a decision support aid that enables EC staff to make quick and accurate decision to reallocate the trapped victims to the safest EC.

B. Requirement Model

There are two views in requirement modeling; structured analysis and object-oriented analysis. In structured analysis, both data and the processes that transform the data are considered as separate entities. On the other hand, object-oriented analysis integrate the entire specific data and the processes that create, read, update or delete the data and these are named with the object. Unified Modeling Language (UML) is one of the techniques that is based on object-oriented analysis and is well-known and widely used in education and academic papers (Petre, 2013). Pressman (2010) proposes a combination of both approaches which consist of four elements of requirements modeling; namely scenario based models, class models, behavioral models and flow models. According to Wiley (2003), use case diagram, sequence diagram, and class diagram have already covered 80% of requirement modeling. This statement is supported by Dennis, Wixom, &Roth (2015) who suggested that use case diagrams, class diagrams, sequence diagrams, and state diagrams are the four core techniques of UML in practice.

Based on the literature review discussed above, a requirement model of AEECM will be visualized by three cores of UML requirements modeling that consist of use case, class diagram, and sequence diagram.

III METHODOLOGY

There are five sequential phases in this study. The first phase involves gathering software requirement specification from all stakeholders and from the literature. These literature provide views on the activities during flood disasters and what solutions have been proposed by previous researches. It also describes the existing techniques used to gather the requirements, and how to present them. This information helps in gathering the software requirement from users. The interview technique is used to collect the requirement from the stakeholders. The stakeholders that are involved in this development are the District Officer (JPBD), the Administrators, the Welfare Officers, the Rescuers and the end users, i.e. the village heads (*JKK Kampung*). Requirement Definition Statement is the outcome of this phase.

The second phase involves modeling the requirements. UML techniques are used to model the requirement. These requirements are presented in Use Case Diagram, Class Diagram, and Sequence Diagram. Use Case Diagram is further clarified in Use Case Specification, whilst three design patterns are applied in creating the Class Diagram and Sequence Diagram.

The third phase includes the development of AEECM by applying Spring MVC Framework, Factory Design Pattern, and Repository Design Pattern (Johnson, et al, n.d.), (Gamma, n.d.), (Evans, 2003). Model-View-Controller (MVC) is a design pattern that separates application code in three layers, namely Model, View and Control.

The fourth phase involves verification of the requirement model (Use Case Diagram, Use Case Specification, Class Diagram, and Sequence Diagram). Undertaking verifications is to ensure the created model is reliable and the application is operating as expected. The verification involves examining the requirement model against collected data. Inspection technique review was used for verifications (Galin, 2004) and the questionnaire is used to record the feedback. The questionnaire template by Al-Tarawneh (2014) was used in creating the questionnaire for this study. The experts consist of 3 persons who are involved in verifying the model. These experts have more than 5 years of experience in evaluating requirement models. The fifth phase involves preparing the thesis and articles for publication.

IV THE PROPOSED AEECM

AEECM is proposed as a decision support tool to provide solutions for relocation of victims to other ECs when the existing centers are flooded. The proposed solution will provide information on the number of victims that are required to be transported to the new ECs. The application is developed on a web based platform and Android mobile application. The proposed solution operates using Firefly multi-objective optimization algorithm that creates an optimal schedule for the relocation of victims and resources for an EC. The AEECM application can be downloaded from Google Play and installed on Android devices.

AEECM is developed for authorities who are managing evacuation centers; system administrators, District Officers (JPDB), Welfare Departments (*JabatanKebajikanMasyarakat*), welfare officers, rescuers, and village heads (*JKK Kampung*). As a start, Kuala Krai, Kelantan is chosen, involving 109 evacuation centres from four districts; Guchil, Mengkebang, ManekUrai, and Dabong. The following are the use cases that have been identified for this system: (UC-1) Manage User Account; (UC-2) Manage Role; (UC-3) Manage Role Authorization; (UC-4) Sign In; (UC-5) Update Personal Information; (UC-6) Manage EC Information; (UC-7) Update data related to river level; (UC-8) Update Current Evacuees at EC; (UC-9) Request to close EC; (UC-10) Display Suggestion Evacuation Plan for the effected EC; (UC-11) Receive Alert Warning to Evacuate the EC; (UC-12) View Current Condition of EC; (UC-13) Manage River Information; (UC-14) Manage Station Information; (UC-15) Authorization; (UC-16) Update My Password; (UC-17) View EC on Map.

For managing an EC, a system administrator operates the information related to all ECs (name of EC, address of EC, EC's GPS location, maximum number of evacuee capacity, EC distance to other ECs, EC distance from the nearest river, *JKK Kampung* in charge at each EC, including the name and contact number). The system administrator also has to update data related to water level at every one hour by extracting information from the Department of Drainage and Irrigation website for selected rivers. He also manages the request for EC closure, either from head of villagers or as instructed by District Officers. When an EC is requested to be closed, the system will generate a reallocation plan by suggesting a list of ECs with the capacity of evacuee to be moved. A system administrator is able to view up-to-date conditions of ECs: (1) Red for ECs that are closed as they were submerged; (2) Orange for ECs that are needed to be closed due to rising water level – alert will be shown; (3) Yellow for ECs that is reaching 90% full - alert will be shown; (4) Green for ECs that have 75%

capacity; and (5) Blue for ECs that have 50% capacity.

The eight operations for managing an EC are: (1) Search to retrieve existing EC; (2) Clear to reset the screen to the initial state; (3) Add to create a new EC; (4) Edit to modify information on EC; (5) Assign to assign JKK as the person-in-charge to EC; (6) UnAssign to unassigned JKK from EC; (7) Delete to delete EC from DB (database); and (8) Open Evacuees Entry to open evacuees entry screen.

Figure 1 illustrates the class diagram of the eight operations for managing an EC, whereas Figure 2 to Figure 8 illustrate the sequence diagram for those eight operations. Each of the operations in the sequence diagram is detailed out in other references. Due to space limit, the sequence diagram's explanation and its reference diagram is not presented in this article.

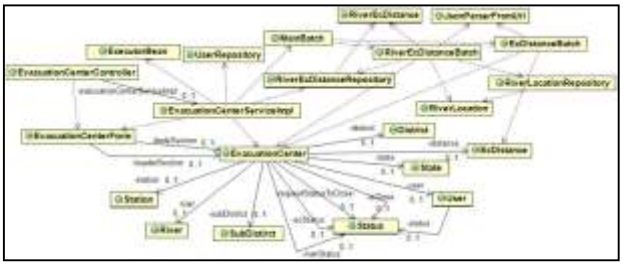

Figure 1. UC-6 Manage EC Class Diagram

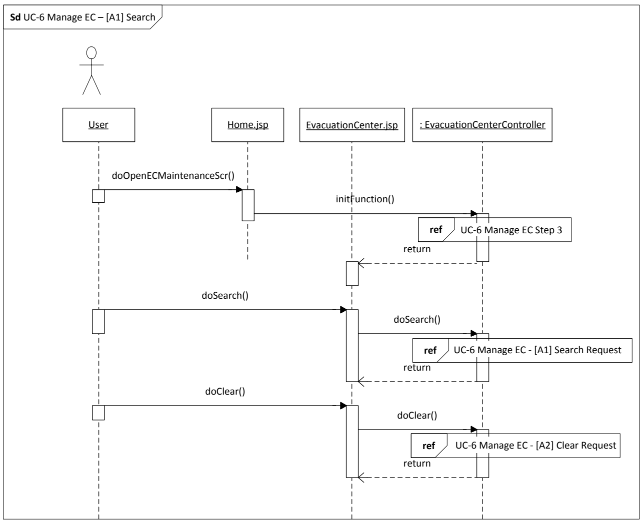

Figure 2. Sd UC-6 Manage EC – [A1] Search

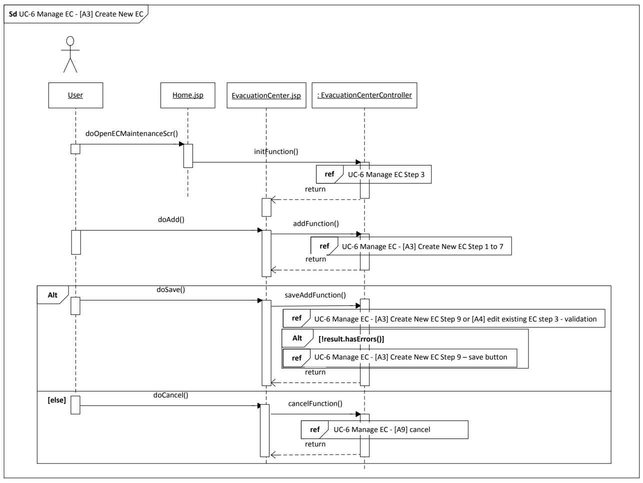

Figure 3. Sd UC-6 Manage EC – [A3] Create New EC

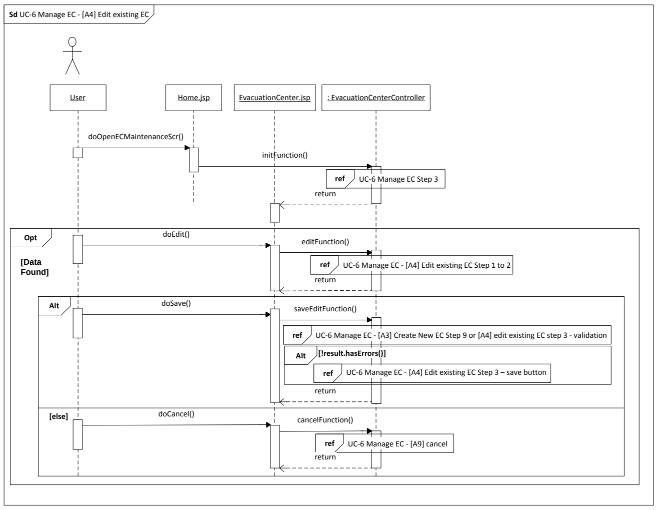

Figure 4. Sd UC-6 Manage EC – [A4] Edit Existing EC

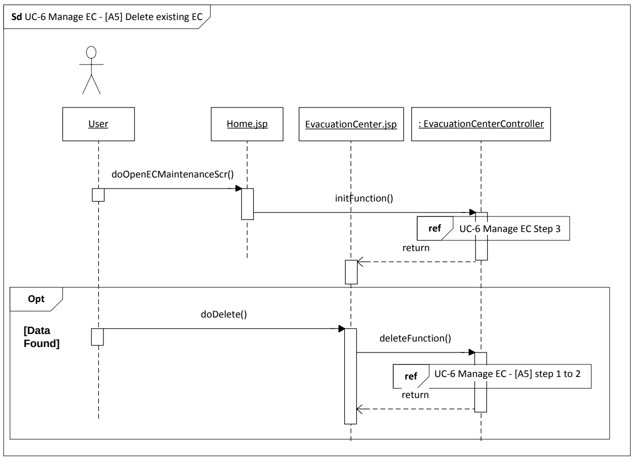

Figure 5. Sd UC-6 Manage EC – [A5] Delete Existing EC

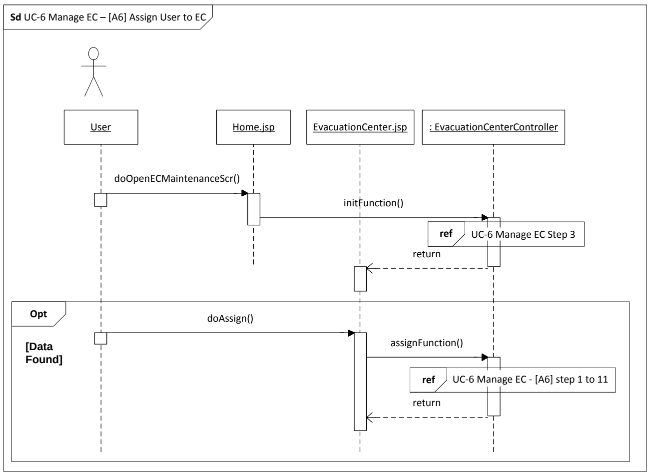

Figure 6. Sd UC-6 Manage EC – [A6] Assign User to EC

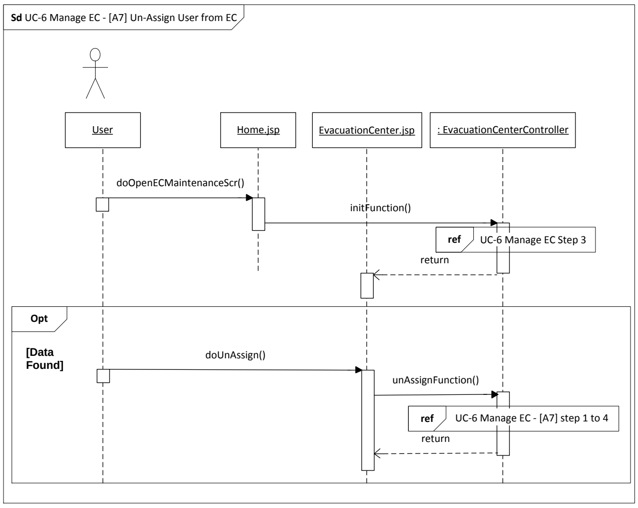

Figure 7. Sd UC-6 Manage EC – [A7] UnAssign User to EC

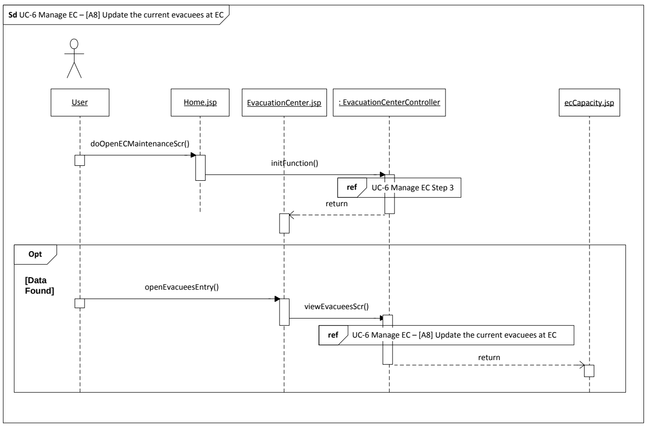

Figure 8. Sd UC-6 Manage EC – [A8] Update the current evacuees at EC

V RESULT

Verification was conducted on the proposed requirement model. Use Case Diagram, Use Case specification, Class Diagram, and Sequence Diagram were verified by the experts that consist of three experts who have more than 5 years' experience in evaluating requirement models. The questionnaire was created to record the feedback.

Table 1 shows the results of the questionare answered by the expert.

Table 1. Verification Result.

No	Criteria	Majority	
		With Modification	Without Modification
1.	Correctness	4 UCs	13 UCs
2.	Ambiguity	0 UCs	17 UCs
3.	Completeness	4 UCs	13 UCs
4.	Consistency	2 UCs	15 UCs
5.	Understandability	4 UCs	13 UCs
6.	Redundancy	0 UCs	17 UCs

Based on the results, it can be said that the requirement models produced fulfill the evaluation verification criteria. However, corrections and improvements have to be made.

Based on the responses from the experts, several suggestions have been provided. The following are the suggestions to improve the requirement model: (1) equalise the number of use cases to number of use case specification (2) integrate validate user into sign in (3) state the relationship between actor and sign in use case diagram (4) use the term button on edit operation (5) state what happens behind the system (internal process) (6) state the link between use case (include and extends) (7) provide sequence diagram in high level design (8) add pre-condition on use case specification (9) Quit restricted to interface navigation (10) simplify user registration process (11) display result after generating evacuation plan (12) regenerate evacuation plan (13) provide information on use case specification on which role user will receive notification.

VI RESEARCH CONTRIBUTION

This study will contribute to the practical aspect of managing flood by providing a decision tool to assist in the management of flood , evacuation centers and flood victims in every flood-affected state. Theoretically, the study contributes to the design of flood decision aid system, whereby requirement model constructed can be used to guide designers and programmers in creating similar systems.

VII CONCLUSION

A requirement model is used to represent users' requirements. It is created through a process model. AEECM requirement model is a model derived to support a user in making decisions based on the provided solutions to reallocate flood victims to safer places. This requirement model has been verified by the experts and a prototype has been developed in order to validate the requirement model.

In conclusion, AEECM can be a more comprehensive decision aid model if it is designed and handled carefully. There are several features of AEECM that have been identified for future improvement. One of them is a feature that requires a system administrator to manually update information of water level every one hour. As data of water level is one of the crucial information required in the decision making, the process of extracting relevant infromation from the Department of Irrigation and Drainage needs to be automated. This improvement can be implemented in future work.

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